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Hemodynamic responses of the caudal artery to toxic tall fescue in beef heifers[1]

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ABSTRACT: Color Doppler ultrasonography was used to compare blood flow characteristics in the caudal artery of heifers fed diets with endophyte (*Neotyphodium coenophialum*) infected (E+) or noninfected (E–) tall fescue seed. Eighteen crossbred (Angus × Brangus) heifers were assigned to 6 pens and were fed chopped alfalfa hay for 5 d and chopped alfalfa hay plus a concentrate that contained E– tall fescue seed for 9 d during an adjustment period. An 11-d experimental period followed, with animals in 3 pens fed chopped alfalfa hay plus a concentrate with E+ seed and those in the other 3 pens fed chopped hay plus concentrate with E– seed. Color Doppler ultrasound measurements (caudal artery area, peak systolic velocity, end diastolic velocity, mean velocity, heart rate, stroke volume, and flow rate) and serum prolactin were monitored during the adjustment (baseline measures) and during the experimental period. Three baseline measures were collected on d 3, 5, and 6 during the adjustment period for comparison to post E+ seed exposure. Statistical analyses compared the proportionate differences between baseline and response at 4, 28, 52, 76, 100, 172, and 268 h from initial feeding of E+ seed. Serum prolactin concentrations on both diets were lower ($P < 0.001$) than baseline beginning at 4 h from the start of the experimental period. However, trends in serum prolactin concentrations for heifers on the E– diet suggested ambient temperature was affecting these concentrations. Caudal artery area in E+ heifers had declined ($P < 0.10$) from baseline by 4 h and was consistently lower ($P < 0.05$) for the remainder of the period. Heart rates for E+ heifers were lower than the baseline rate from 4 ($P < 0.10$) to 100 ($P < 0.001$) h, but were similar ($P > 0.10$) to the baseline for 172 and 268 h measures. Blood flow in E+ heifers was consistently lower than the baseline from 4 ($P < 0.05$) to 172 ($P < 0.001$) h, but was similar to the baseline at 268 h when heart rate was similar to the baseline rate. Caudal artery areas for the E– diet were similar to baseline areas except at 100 h when it was greater than baseline. Heart rates and flow rates for E– heifers did not differ ($P > 0.10$) from baseline measures during the experimental period. Results indicated that onset of toxicosis was within 4 h of cattle exposure to E+ tall fescue and is related to vasoconstriction and reduction in heart rate.

Key words: beef cattle, tall fescue, *Schedonorus arundinaceus*, fescue toxicosis, color Doppler ultrasonography, vasoconstriction

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INTRODUCTION

Tall fescue [Schedonorus *arundinaceus* (Schreb.) Dumort = *Festuca arundinacea* (Schreb.); Soreng et al., 2001] is a cool-season perennial grass that covers approximately 15 million ha in the eastern United States (Thompson et al., 2001). An endophytic fungus is found in plants of greater than 90% of tall fescue pastures (Sleper and West, 1996) and produces alkaloid toxins that induce the fescue toxicosis malady. Toxicosis has symptoms that include retention of rough hair coat, elevated body temperature, labored respiration, and decreased serum prolactin (Schmidt and Osborn, 1993). Ergot alkaloids bind biogenic amine receptors in the peripheral vasculature (Oliver, 2005) and may reduce the animal's ability to dissipate body heat, which can lead to heat stress at the onset of high ambient temperature (Hemken et al., 1981; Spiers et al., 2005).

Experiments have monitored steers grazed on endophyte-infected (**E+**) fescue and subsequently placed on nontoxic diets. Aiken et al. (2006) determined that 144

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to 192 h was needed for rectal temperatures to decline from 40.5 to 39.5°C. Stuedemann et al. (1998) reported a 67% decrease in urinary alkaloid concentrations within 24 h after steers were switched from E+ to endophyte noninfected (**E**–) tall fescue pastures. These experiments showed that heat stress associated with grazing E+ fescue can be reduced in a short period of time, but studies have been lacking on the time following consumption of ergot alkaloids during which a physiological response is mediated.

Color Doppler ultrasonography has been used to study blood flow characteristics in horses (Raisis et al., 2000; Hoffman et al., 2001). The technology has the repeatability to provide objective measures of vasoconstriction and blood flow in cattle exhibiting toxicosis (King, 2006).

To study effects of ergot alkaloid exposure on cattle hemodynamics, an experiment was conducted to evaluate and compare hemodynamics in the caudal arteries of heifers fed diets with E+ or E– fescue seed.

MATERIALS AND METHODS

The experimental protocol was reviewed and accepted by Institutional Animal Care and Use Committee at the University of Kentucky.

Eighteen crossbred (Angus × Brangus) heifers (12 to 14 mo of age) were used in the experiment. Diets of heifers did not contain ergot alkaloids from birth until the beginning of the experiment. Heifers were on Bermudagrass [*Cynodon dactylon* (L.) Pers.] pasture before weaning in October at the USDA-ARS Dale Bumpers Small Farms Research Center in Booneville, AR. The calves were group-fed Bermudagrass hay and concentrate until late November, when they were transported to the University of Kentucky Animal Research Center in Versailles, KY. Heifers were placed in pens and fed a corn silage-concentrate ration until the start of the experiment.

Heifers were assigned to 6 pens (3 heifers/pen) by BW [375 ± 17 kg (s.d.)] so that mean BW and variance in BW were similar across pens. During an adjustment period, chopped alfalfa hay was fed to heifers in each pen for 5 d followed by feeding of chopped alfalfa (54.4% of DM) and concentrate with E– seed (45.6% of DM) for 9 d. Treatment diets, containing E– or E+ tall fescue seed, were assigned to pens in a completely randomized design with 3 replications. An 11-d experimental period followed with the feeding of both treatment diets. Composition of the concentrate was ground soybean hulls (47.6% of DM), tall fescue seed (47.6% of DM), mineral premix (1.2% of DM), and molasses (3.6% of DM). The alfalfa-concentrate mixtures were fed ad libitum during the adjustment and experimental periods at 0900 h each morning. Orts were collected daily before feeding, dried in a forced-air oven at 60°C for 72 h, and weighed to estimate daily DM consumption.

Each concentrate mixture was subsampled on the first and last day of the experimental period. Samples were stored frozen, freeze dried in a model 18DX485A freeze drier (Botanique Preservation Co., Peoria, AZ), ground through a 1-mm screen, and assayed for ergovaline and ergovalanine by HPLC florescence using a modification of a procedure developed by Yates and Powell (1988). Intra- and interassay CV for ergovaline were 0.77 and 7.7%, respectively, and for ergovalinine were 0.16 and 7.2%, respectively. The sensitivity of detection was 0.1 μg/g of DM.

Baseline ultrasound measures were taken during the adjustment period on d 3, 5, and 6. All scanning sessions began at 1300 and ended at approximately 1500. Ultrasound measures were taken during the experimental period at 4, 28, 52, 76, 100, 172, and 268 h relative to initial feeding of E+ seed. Ultrasound scans of the caudal artery at the fourth coccygeal vertebra were taken using an Aloka 3500 Ultrasound Unit (Aloka Inc., Wallingford, CT) with a UST-5542 (13 MHz) linear array transducer set to a 2-cm depth. Three cross-sectional color Doppler flow scans were taken to determine the mean artery lumen area. After the freezing of an individual scan, frames stored in the cine memory of the unit were searched to store the image exhibiting the maximum flow signal and assumed to be at peak systolic phase (Figure 1). The flow signal was traced to estimate the lumen area. Three color Doppler spectra with a longitudinal transducer orientation also were collected (Figure 2). Spectra were taken with a color Doppler pulse frequency of 6 MHz, and a correction angle of 25° was used. The sample volume was set at 0.5 mm. Doppler gain was set at 40, the maximum setting before noise became apparent. Peak systolic velocity, end diastolic velocity, mean velocity, pulsatility index, stroke volume (artery area × mean velocity × stroke time), and flow rate per minute (volume per beat × heart rate) were measured over 3 cardiac cycles within each scan and then averaged over the 3 scans. Pulsatility index was used as an indicator of vascular resistance (Petersen et al., 1997). Ultrasound measurements were performed by a trained technician who had no knowledge of treatments imposed on the individual heifers.

After collection of the ultrasound measures on each measurement day, a blood pressure cuff (Omron Healthcare Inc., Vernon Hills, IL) was wrapped around the base of the tail, and 3 systolic and diastolic pressures were recorded and averaged.

Approximately 10 mL of blood was collected from the jugular vein of each heifer during the adjustment period on d 3, 5, and 6, and at 28, 52, 76, 100, 172, and 268 h relative to initial feeding of E+ seed. Blood was centrifuged for 15 min at 10,000 × g to obtain serum, which was stored frozen (0°C). Serum was assayed for prolactin by RIA following the procedures of Bernard et al. (1993). Intra- and interassay CV were 6.0 and 11.0%, respectively, and sensitivity of detection was 0.05 ng/mL.

The Shapiro-Wilk test for normality (Schlotzhauer and Littell, 1997) showed the flow rate data to be nor-

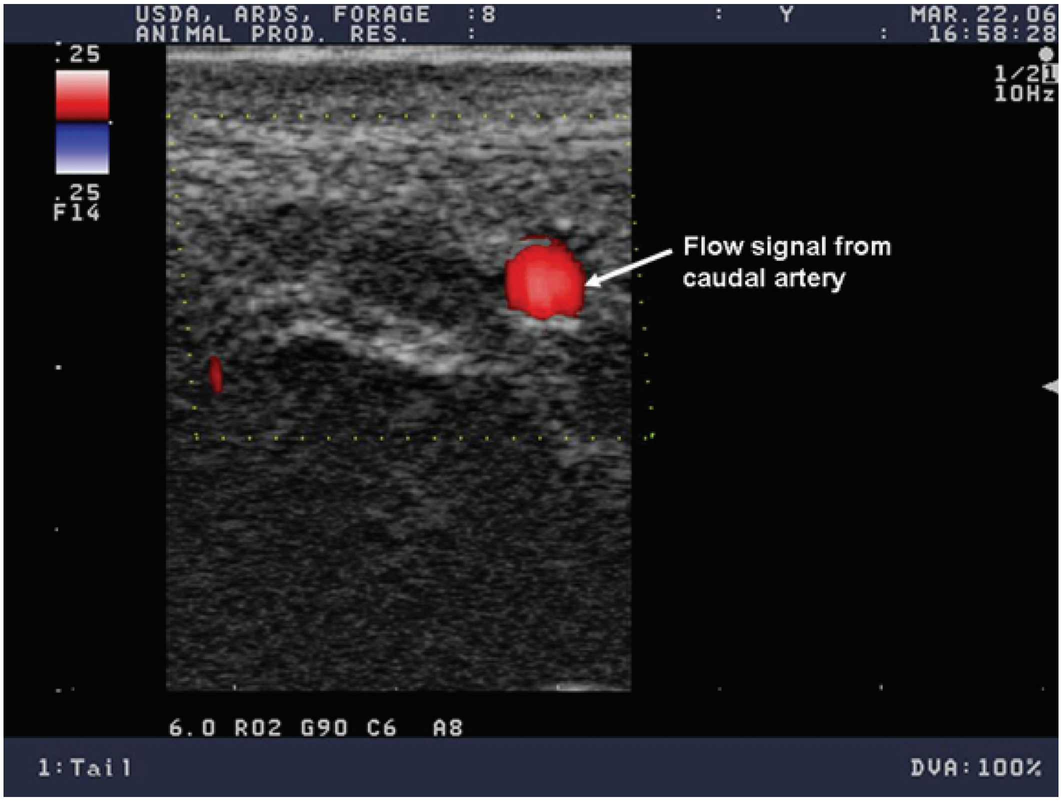

Figure 1. Ultrasound scan at a 2-cm depth of the cross section of the caudal artery taken at the fourth coccygeal vertebra. Red Doppler flow signal delineates the area of flow through the artery.

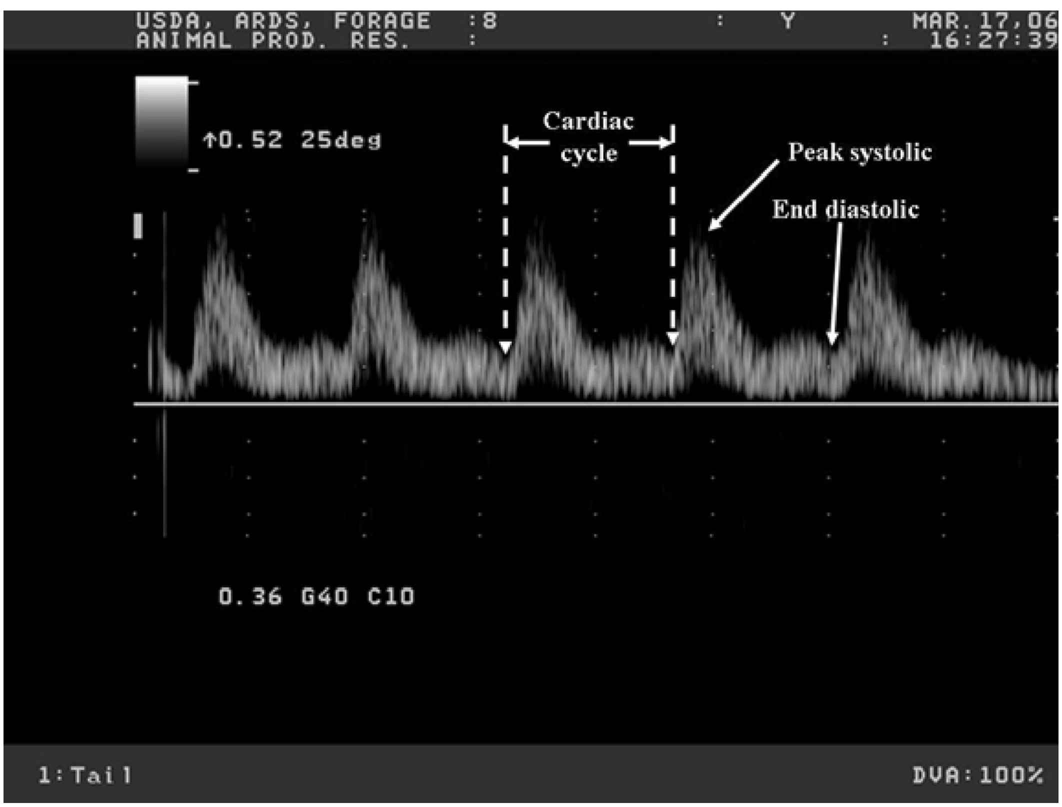

Figure 2. Doppler spectra from a longitudinal, color Doppler, ultrasound scan.

mally distributed for the E+ heifers (W = 0.94, P = 0.21) but not for the E– heifers (W = 0.79, $P < 0.001$). Therefore, the proportionate difference between the response measures and the baseline averages [($\text{response}_{\text{experimental period}} - \text{baseline}_{\text{adjustment period}}$)/$\text{baseline}_{\text{adjustment period}}$] were statistically analyzed using the paired t-test (SAS Inst. Inc., Cary, NC) for each treatment diet at each hour from the initial feeding of E+ tall fescue seed. The analysis used baseline measures for individual pens to calculate the proportionate difference for replicates.

RESULTS

Toxin Concentrations

Chopped alfalfa hay plus concentrate containing E+ seed had 0.85 μg of ergovaline and 360 ng of ergovalanine/g of DM, and the hay and concentrate mixture with E– seed had no detectable concentrations of either ergopeptine. Ergovaline concentrations of 0.85 μg/g of DM in the E+ diet were greater than 0.65 to 0.75 μg/g of DM shown to elicit toxicosis symptoms in steers (Hill et al., 1994) and sheep (Looper et al., 2007).

Diet Consumption

Daily DM consumption averaged 6.3 ± 0.5 kg per heifer during the adjustment period when the E– diet was fed to all pens. Consumption was therefore approximately 1.7% of BW. During the experimental period, DM consumption by heifers fed the concentrate with E– seed was 10.7 ± 0.5 and 9.0 ± 0.8 kg of DM/heifer for heifers fed the concentrate with E+ seed. Although consumption during the experimental period was high for both treatments, there was a weak tendency ($P < 0.15$) for heifers on the E– treatment to consume a greater percentage of BW in DM (E– = 2.9%; E+ = 2.4%).

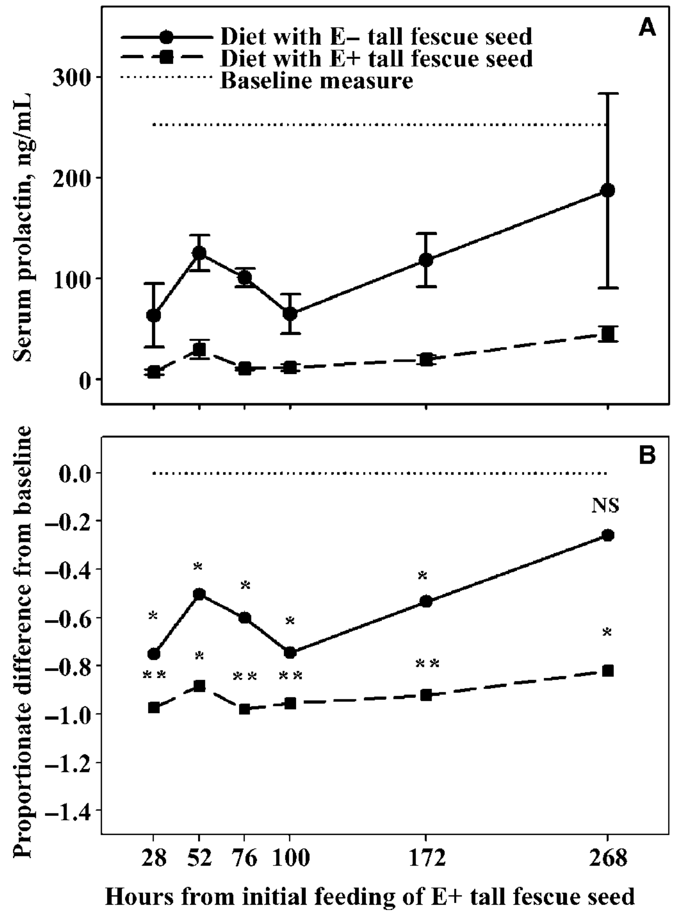

Figure 3. Trends over the experimental period in (A) serum prolactin concentrations and (B) proportionate differences between prolactin concentration responses and baseline measures taken during the adjustment period for heifers fed diets with endophyte-infected (E+) or noninfected (E–), tall fescue seed. Baseline measures are the averages across both diets. Statistical differences are denoted by †$P < 0.10$; *$P < 0.05$; **$P < 0.001$; and NS = not significant, $P > 0.10$.

Serum Prolactin

During the experimental period, serum prolactin averaged 20 ± 4 ng/mL on the E+ diet and 112 ± 19 ng/mL on the E– diet (Figure 3). Baseline measures for both groups were high (252 ± 35 ng/mL), but declined ($P < 0.001$) on both diets by 4 h from the initial feeding of E+ seed. Prolactin concentrations for both diets were less ($P < 0.001$) than baseline concentrations at 28 h after the initial feeding of E+ seed. Prolactin concentrations were lower ($P < 0.01$) in E+ heifers for the remainder of the experimental period. However, prolactin concentrations in E– heifers generally increased beyond 96 h and were not different ($P > 0.10$) from baseline concentrations by 268 h.

Color Doppler Ultrasound Measures

Baseline caudal artery area for the 2 diets averaged 4.8 ± 0.2 mm^2 (Figure 4). Artery area with the E+ diet was less ($P < 0.10$) than the baseline area by 4 h from the initial feeding of the E+ diet. Further decline in artery area ($P < 0.001$) below baseline level in E+ heifers occurred for the remainder of the experimental period. During this time, caudal artery area in E+ heifers averaged 2.8 ± 0.1 mm^2, with the lowest area (2.0 mm^2) being detected at 28 h, whereas areas in E– heifers averaged 5.4 ± 0.2 mm^2 during the experimental period and varied considerably within and between pens.

Baseline heart rates for the treatment diets averaged 106 ± 3 beats/min (Figure 5), and heart rate with the E+ diet was lower ($P < 0.10$) than the baseline rate ($P < 0.10$) at 4 h from initial feeding of the E+ diet. Lower heart rates than the baseline ($P < 0.05$) were observed from 28 to 100 h, but were similar to the baseline rate at 178 and 268 h. Heart rate with the E– diet did not vary from the baseline rate except for the higher rate that was detected ($P < 0.001$) at 268 h.

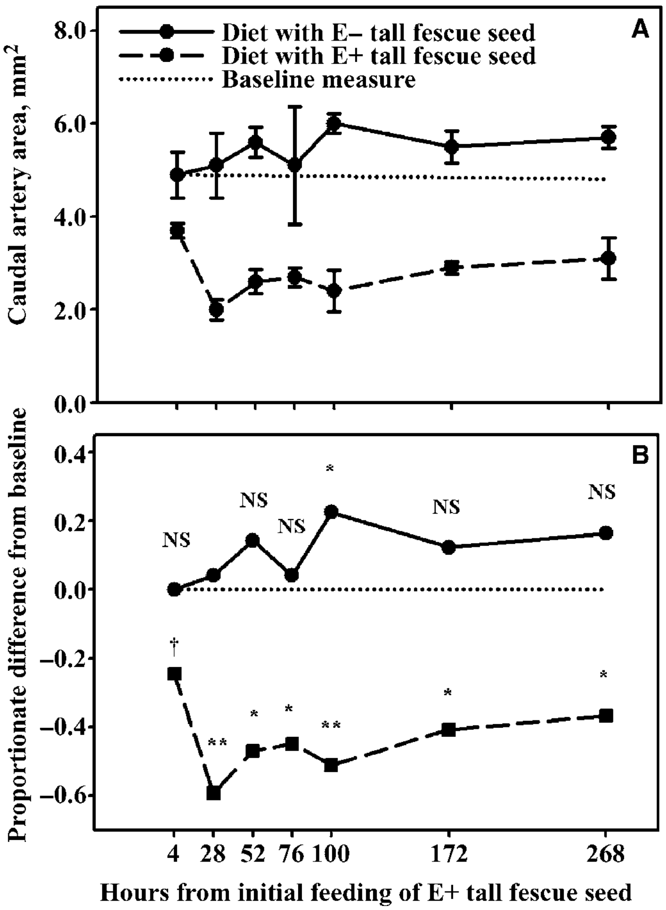

Figure 4. Trends over the experimental period in (A) caudal artery area and (B) proportionate differences between artery area responses and baseline measures taken during the adjustment period for heifers fed diets with endophyte-infected (E+) or noninfected (E–) tall fescue seed. Baseline measures are the averages across both diets. Statistical differences denoted by †P < 0.10; *P < 0.05; **P < 0.001; and NS = not significant, P > 0.10.

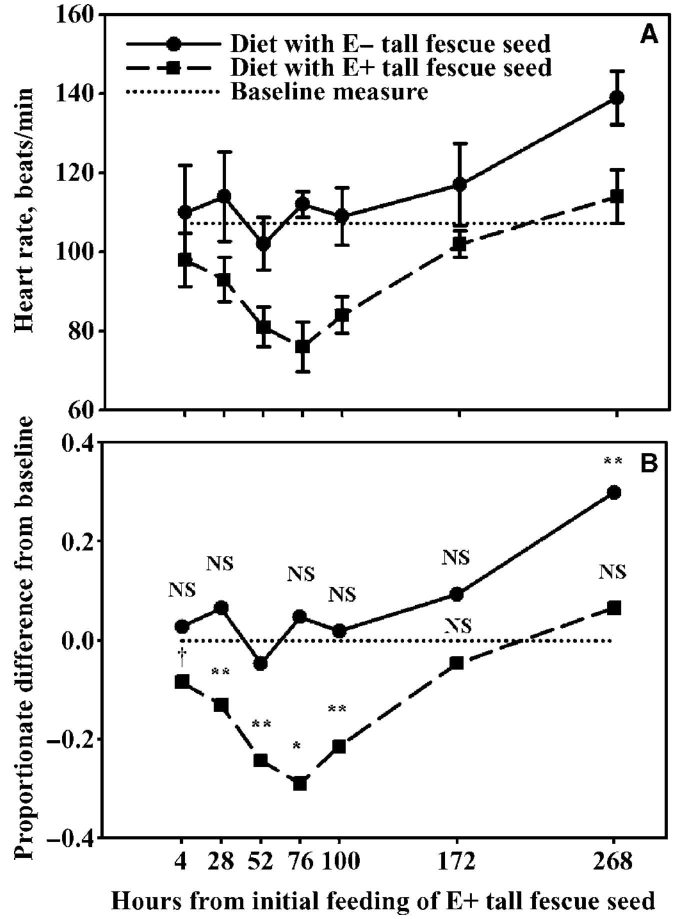

Figure 5. Trends over the experimental period in (A) heart rate and (B) proportionate differences between heart rate responses and baseline measures taken during the adjustment period for heifers fed diets with endophyte-infected (E+) or noninfected (E–) tall fescue seed. Baseline measures are the averages across both diets. Statistical differences denoted by †P < 0.10; *P < 0.05; **P < 0.001; and NS = not significant, P > 0.10.

There were no consistent differences (P > 0.10) from baselines for either diet in peak systolic velocity, end diastolic velocity, mean velocity, or pulsatility index (Table 1). Peak systolic velocity was higher (P < 0.05) than the baseline velocity only at 76 h from initial feeding of the E+ diet, but with no corresponding increase in pulsatility index to indicate an increase in resistance. Pulsatility index was greater (P < 0.05) than the baseline index at 4 h, but was similar (P > 0.10) to baseline indices for the remainder of the period with the exception of the greater (P < 0.10) index at 172 h. End diastolic velocity at 76 h was lower (P < 0.10) than the baseline measure.

Baseline stroke volumes for the 2 diets averaged 0.28 ± 0.02 mL/s (Figure 6). Stroke volume with the E+ diet was less (P < 0.05) than the baseline volume at 4 and 28 h from initial feeding of the E+ diet, but was not different (P > 0.10) from the baseline at 52 and 76 h. Stroke volume was less (P < 0.10) than the baseline rate at 100 and 178 h as heart rate increased in E+ heifers. Stroke volume at 268 h was similar (P > 0.10) to the baseline when mean velocity was numerically the same as the baseline.

Baseline blood flow rates through the caudal artery for both treatment diets averaged 29.6 ± 7.7 mL/min, and averaged 35.7 ± 4.9 and 15.9 ± 1.0 mL/min for E– and E+ diets, respectively, during the experimental period (Figure 7). Blood flow with the E+ diet was less (P < 0.05) than the baseline rate at 4 h, and reduced (P < 0.10) flow was observed for the remainder of the period until 268 h (P > 0.10) when flow rate was similar to the baseline.

Blood Pressures

There were no consistent changes in systolic or diastolic pressures during the experimental period. Systolic pressure in E+ heifers at 100 h from initial feeding

Table 1. Proportionate differences between response measures in the experimental period and baseline measures in the adjustment period for color Doppler ultrasound measures of peak systolic velocity (PSV), end diastolic velocity (EDV), mean velocity (MNV), pulsatility index, and systolic and diastolic blood pressures[1]

			Hours from initial feeding of E+ tall fescue seed							
Item	Diet	Baseline[2]	4	28	52	76	100	172	268	SEM[3]
PSV, cm/s	E+	22.4	–0.13	–0.08	0.13	0.17*	–0.13	–0.04	0.05	0.04
	E–	21.8	–0.14	–0.15*	0.09	0.05	–0.18**	–0.16	–0.23*	0.04
EDV, cm/s	E+	2.5	–0.48	–0.72*	0.12	–0.52*	–0.30	–0.47	–0.16	0.13
	E–	3.5	–0.50*	–0.57*	–0.24	0.03	–0.71*	0.05	–0.28	0.10
MNV, cm/s	E+	10.4	–0.32*	–0.11	0.21	0.17	–0.16	–0.25*	0.06	0.06
	E–	8.9	–0.17	–0.29	–0.08	0.08	–0.29*	–0.33*	–0.28*	0.04
Pulsatility index	E+	2.3	0.45*	0.03	–0.08	0.06	0.15	0.35†	0.06	0.06
	E–	3.0	0.18	0.66**	0.47	0.08	0.37	0.74†	0.26	0.07
Systolic pressure, mm Hg	E+	146	–0.02	–0.11	–0.13	–0.20	–0.30**	–0.01	–0.13	2.9
	E–	141	0.03	–0.03	–0.07	–0.09	–0.05	–0.12*	–0.03	1.5
Diastolic pressure, mm Hg	E+	86	–0.04	–0.02	–0.21†	–0.20*	–0.16†	0.10	–0.08	3.1
	E–	77	0.06	0.09	–0.06†	–0.06	0.00	–0.06	0.11	2.6

[1]PSV, EDV, MNV, and pulsatility index were taken from the caudal artery at the fourth coccygeal vertebra; and systolic and disastolic pressures were taken from the base of the tail.
[2]Baseline measures for individual pens were used for statistical analyses.
[3]Standard error of the mean for proportionate difference from baseline measure over hours from initial feeding of E+ tall fescue seed.
†,*,**Proportionate difference from baseline measure [(response$_{\text{experimental period}}$ – baseline$_{\text{adjustment period}}$)/baseline$_{\text{adjustment period}}$] is significant at $P < 0.10$, $P < 0.05$, and $P < 0.01$, respectively.

of the E+ diet was less ($P < 0.01$) than the baseline pressure and coincided with a diastolic pressure that was less ($P < 0.10$) than the baseline. Diastolic pressure also was less than the baseline at 52 ($P < 0.10$) and 76 ($P < 0.05$) h.

DISCUSSION

Temperature and Heat Indices

Ambient temperatures during the adjustment and experimental periods averaged 5.4 ± 4.6°C, which likely resulted in the cattle being below or at the lower limits of their thermoneutral zone. Temperatures fell slightly below 0°C on the first and second days of the experimental period, but tended to increase for the remainder of the experimental period until the last day of the period when the highest mean ambient temperature (16.1°C) was recorded. Response to ergot alkaloids is increased at ambient temperatures above thermoneutral (Hemken et al., 1981; Spiers et al., 2005). Experiments have shown increases in core body temperature of cattle consuming E+ tall fescue seed relative to those on nontoxic diets as ambient temperature is increased above 31°C (Aldrich et al., 1993; Al-Haidary et al., 2001). Spiers et al. (1995) reported for rats, injected with ergovaline and subjected to a cold challenge (6.8 to 9.1°C, that tail-temperature was 1.0°C lower than those not injected with ergovaline. The decline in tail-skin temperature was due to a reduction in overall body temperature because of the likelihood of intense vasoconstriction in response to the cold challenge. Thermoregulatory response to ergot alkaloids appears to be dependent on the magnitude of thermal stress (Spiers et al., 1995). Lack of elevated rectal temperatures for cattle grazing endophyte-infected tall fescue has, in part, been attributed to mild ambient temperatures. Heat stress was not imposed on the heifers in the present experiment because the objective of the experiment was to measure response of the vascular system to ergot alkaloids without combining the effects of high ambient temperature.

Serum Prolactin

Declines in prolactin concentration coincided with a substantial decrease in ambient temperatures on the first day of experimental period. This agrees with findings that serum prolactin concentrations decrease in cattle in response to decreased ambient temperature (Tucker and Wettemann, 1976; Tucker et al., 1991). Tucker and Wettemann (1976) reported that serum prolactin in heifers decreased linearly as ambient temperature was reduced from 21.0 to 4.5°C, which was similar to the range of temperatures observed in the present experiment.

Prolactin concentrations with the E+ diet were less ($P < 0.001$) than baseline measures for the entire experimental period. Prolactin concentrations in heifers on the E– diet followed a similar trend as the ambient temperatures over the experimental period, and the concentrations in heifers on the E+ diet were more consistent beyond 28 h., which reflects the dopaminergic activity of ergot alkaloids on prolactin secretion (Oliver, 2005).

Color Doppler Ultrasound Measures

The tendency for vasoconstriction of the caudal artery by 4 h from the initial feeding of the E+ diet suggests the response to the alkaloids is rapid. Further reduction in caudal artery area between 4 and 28 h from initial

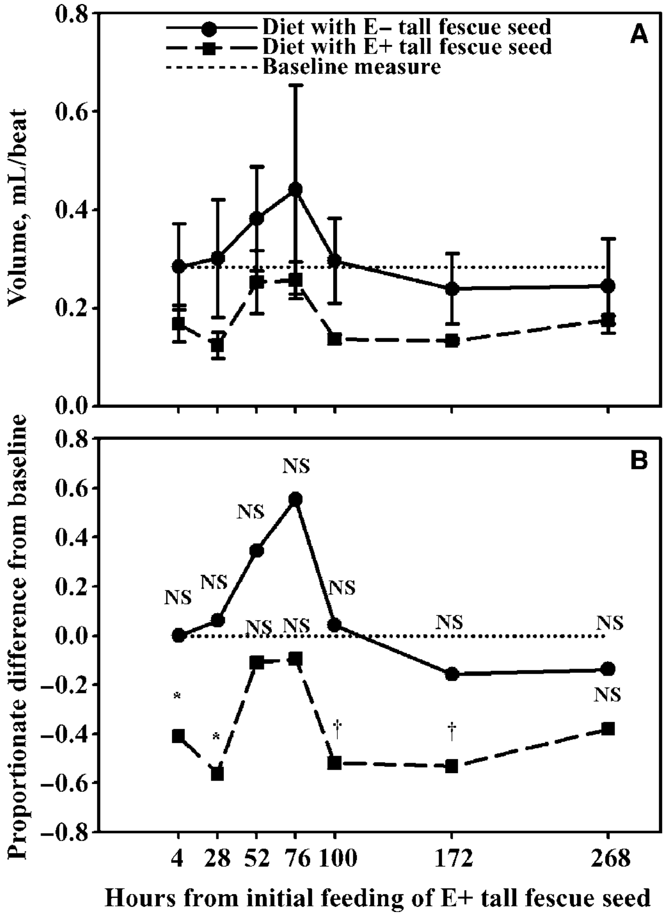

Figure 6. Trends over the experimental period in (A) volume per beat in the caudal artery and (B) proportionate differences between volume per beat responses and baseline measures taken during the adjustment period for heifers fed diets with endophyte-infected (E+) or noninfected (E–) tall fescue seed. Baseline measures are the averages across both diets. Statistical differences denoted by †$P < 0.10$; *$P < 0.05$; **$P < 0.001$; and NS = not significant, $P > 0.10$.

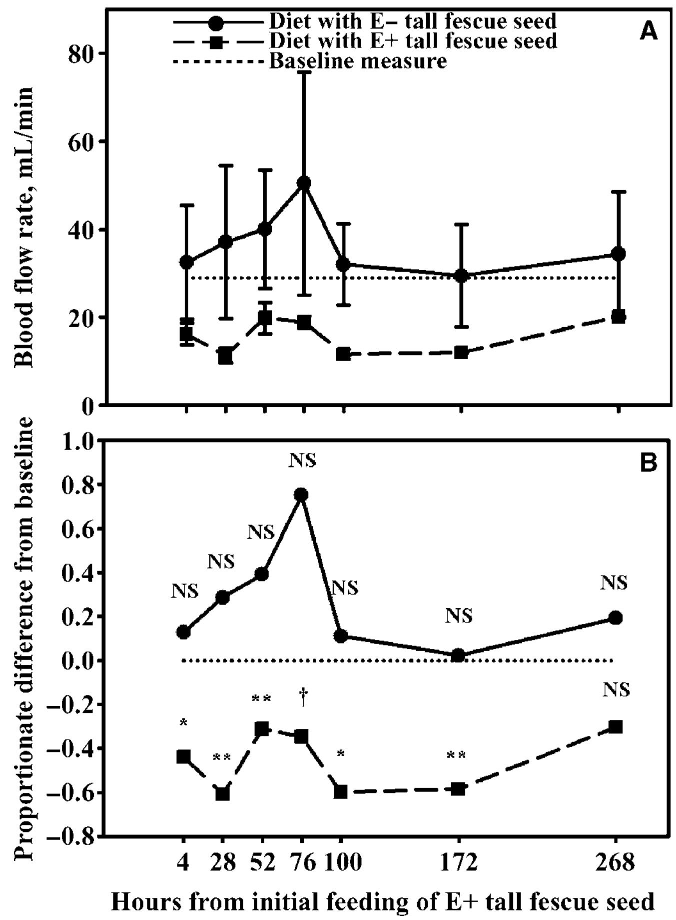

Figure 7. Trends over the experimental period in (A) blood flow rate through the caudal artery and (B) proportionate differences between stroke volume responses and baseline measures taken during the adjustment period for heifers fed diets with endophyte-infected (E+) or noninfected (E–) tall fescue seed. Baseline measures are the averages across both diets. Statistical differences denoted by †$P < 0.10$; *$P < 0.05$; **$P < 0.001$; and NS = not significant, $P > 0.10$.

feeding of the E+ diet indicated ergot alkaloids must reach a threshold concentration in the circulation system before there is maximum constriction.

As the caudal artery constricted with the E+ diet, there was a concurrent 20% reduction in heart rate compared with heifers on the E– diet. It cannot be determined from the data if ergot alkaloids had a direct effect on heart rate, but it likely was a reaction to increases in blood pressure (Berne and Levy, 1992). Although increases in blood pressures in E+ heifers were not observed early in the experimental period, the reflex to the higher blood pressures likely occurred too early for detection. This explanation is supported by the greater pulsatility index observed at 4 h, but was followed by a trend in indices being similar to baseline measures over the remainder of the period. Heart rate reduction in E+ heifers during the experimental period apparently was a reflex to maintain blood pressure and velocity in stable ranges (Berne and Levy, 1992).

Heart rates with the E+ diet did not differ ($P > 0.10$) from baseline rates after 178 h, but this was likely due to concurrent increases in ambient temperature. This was further indicated by the heart rates for E– heifers that were higher than baseline measures at 268 h when the greatest ambient temperature for the period was recorded. Control experiments with cattle undergoing a heat challenge (≥31°C) have reported ergot alkaloids to increase heart rate (Carr and Jacobson, 1969; Walls and Jacobson, 1970). A plausible explanation for this discrepancy between these experiments and those of the present experiment is that ambient temperature could interact with alkaloid concentrations in affecting heart rate.

Stroke volume in the caudal artery of E+ heifers showed to decline from baseline volumes at 4 and 28 h, which coincided with reduced artery areas. Increases in stroke volumes at 52 and 76 h to those similar to baseline values occurred when heart rates were lowest during the experimental period and resulted in greater time per stroke. Stroke volume generally followed a similar pattern as heart rate. Changes in heart rate during the experimental period apparently had a greater influence than vasoconstriction on stroke volume.

Reductions in heart rate with no changes in artery area will increase stroke time to increase volume, but will decrease the number of strokes per unit of time to reduce flow rate. Differences with the E+ diet in flow rates from the baseline at 52 and 76 h when differences from baselines for stroke volume were not significant and heart rates were generally at their lowest suggest that heart rate had a greater influence than vasoconstriction on flow rate through the caudal artery of E+ heifers.

A combination of vasoconstriction of the caudal artery and a reduction in heart rate with the E+ diet resulted in a 55% reduction in blood flow rate. Rhodes et al. (1991) used radiolabeled microspheres to compare blood flows in steers consuming high-endophyte tall fescue with those consuming low-endophyte tall fescue. Blood flows with the high-endophyte diet were reduced by 50% to skin over the ribs, 21.2% to the cerebellum, 51.6% to the duodenum, and 21% to the colon. These results, in conjunction with those of the current study, show that blood flow in cattle exhibiting fescue toxicosis is constricted in peripheral and core body tissues. Therefore, reduction in blood flow would restrict an ability to dissipate core body heat to peripheral tissues, particularly if the animal is exposed to high ambient temperature and humidity.

Caudal artery area, heart rate, and blood flow rate in the present experiment were more variable with the E– than E+ diet. Vasoconstriction caused by the ergot alkaloids likely reduced the influence that environmental stimuli, such as ambient temperature, have on constriction or dilation within the vascular system. Ultrasonic measures varied within and between heifers on the E– diet, which likely was related to the variation in ambient temperature that was observed in the experiment. Consistent artery areas for the remainder of the experimental period, with gradual increases in ambient temperature, further indicated the constriction from the alkaloids on caudal artery area minimizes the effect that ambient temperature has on arterial constriction or dilation.

Results indicated that vasoconstriction of the caudal artery combined with reductions in heart rate occur in cattle in less than 4 h following consumption of endophyte-infected tall fescue. Blood circulation in heifers showed sensitivity to the alkaloids, which suggests that vulnerability to heat stress is increased with short-term grazing of endophyte-infected tall fescue. Further research is needed to determine sensitivity of the bovine vascular system to ergovaline concentrations that are less and greater than the ergovaline concentrations (0.85 μg/g of DM) that were fed in the experiment.

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